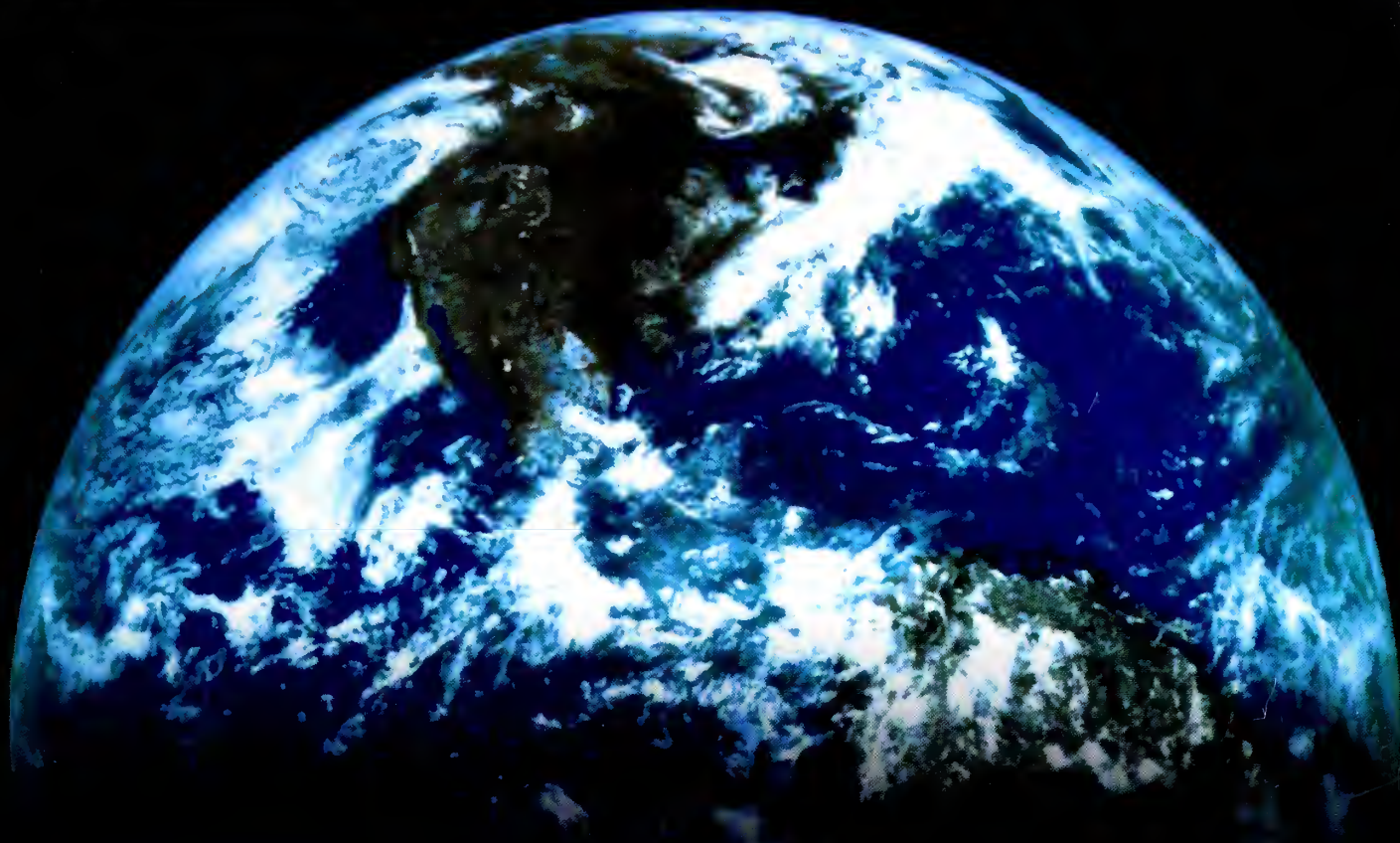




# NAOS

## North American Atmospheric Observing System Program Plan

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*U.S. DEPARTMENT OF COMMERCE  
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## THE NORTH AMERICAN ATMOSPHERIC OBSERVING SYSTEM

### PROGRAM PLAN

*June 1996*



## FOREWORD

Effective weather services save lives. Commerce and the protection of the environment are dependent in real ways on weather and climate information. As societies become more complex, their dependence on weather services will increase. The North American Atmospheric Observing System (NAOS) Program is the central strategy for the design of an improved composite observing system for the 21st Century, which is essential to fulfill societal needs for weather and climate information.

The weather services of North America are faced with critical decisions on the design of the future observing system. Three factors are central to making those decisions.

**Further Improvements In Numerical Weather Prediction Require Better Data:** The progress made with numerical weather prediction has made it possible for field forecasters to provide better tailored, more precise, and more timely weather services to society. At present, however, the observing system is not capable of producing the quality, amounts, and types of data required to continue the progress.

**New Observing Technologies Offer The Promise Of Better Data:** New and improved observing technologies offer the promise of greatly improved data sets. The integration of these technologies into the observing system is a major challenge. The scientific and technological assessment of these technologies will require the close interaction of people in governmental agencies, universities, and cooperative institutes throughout the North American region. Given the processes used in the past to make decisions, the task of bringing these people together as a cohesive force is formidable.

**Limited Resources Must Be Used Efficiently:** The resources of every North American weather service are decreasing at a time when the demands for services are increasing and the potential for major improvement exists. In tandem, the need exists to make better use of the resources that are available. The challenge for management is to find ways to realize that potential through efficiency and through the strategic use of science and systems engineering.

The NAOS Program brings together the scientific, engineering, and management talents that are critical to finding innovative solutions based on science and careful systems analysis. To ensure that the entire North American region and adjacent coastal waters are included in those solutions, a wide range of governmental agencies and scientific organizations of the international participants are represented on the NAOS Council and its work groups. This Program Plan and the separate Implementation Plan set the framework and schedule for the work to be undertaken.

Ronald D. McPherson  
Chair, NAOS Program Council  
June 1996



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## EXECUTIVE OVERVIEW

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The complexities of society and its vulnerability to weather is forecast to increase through the remainder of the 20th century and into the 21st century as technological advances continue to be made in weather-sensitive activities such as commerce, aviation, surface transportation, agriculture, and leisure. These advances have made the well being of the people more, rather than less, dependent on weather information.

Not all weather-related impacts on society can be avoided. However, strategies are available to society to ameliorate dramatically that impact, given adequate forecasts and climatological information. The use of these strategies gives rise to both general and specific societal needs for weather information.

Atmospheric observations over North America and the adjacent oceans make up a major portion of this weather information. The need for ever more complete, accurate, and timely environmental information, coupled with the increasing complexity and cost of operating observing systems, raises the fundamental issue of how to implement and operate an observing system that is capable of meeting the societal demands of the 21st century for improved environmental services. To address this issue, the North American Atmospheric Observing System (NAOS) Program has been created.

**The goal of the NAOS Program is to provide the scientific, technical, and administrative basis for governmental decision processes on how to meet the evolving needs for atmospheric observations over the region of North America and adjacent ocean areas in support of the prediction and assessment of weather and of associated climate services.**

The specific objectives of the NAOS Program are (1) to assess and make recommendations on the short-term steps that can be taken to improve the utility of the existing observing program, and to reduce costs, (2) to define the "best mix" of observing systems, strategies, and technologies that meet the requirements in the most cost-effective way for the evolving Composite Observing System for the 21st Century (COS-21), and (3) to describe the steps

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needed to implement and operate COS-21 and to effectively use the resulting data. The immediate focus of NAOS activities is on the upper air observing program.

The COS-21 design is intended to be the foundation upon which the evolving observing strategy is built. This design will include a definition of the characteristics of the observations to be obtained and their spatial and temporal distribution, and a description of the operational capabilities needed to obtain them. The design, however, is not a specific configuration fixed at a point in time, but instead it is composed of a series of time-phased configurations arrived at by successive iterations through the design and analysis process. Such a flexible design will ensure that the COS-21 continues to represent the "best mix" as the societal needs evolve and observing system capabilities change.

In making its recommendations on the observing program and especially the COS-21, the NAOS Program will focus on governmental activities concerned with (1) watch and warning responsibilities, (2) the preparation of short and medium term regionalized forecasts, (3) the making of global 1-to-3 day forecasts as they apply over the North American continent and adjacent ocean areas, and (4) those climate prediction and assessment responsibilities that rely on observations in common with the first three activities.

The NAOS Program is shaped by two concepts. The first concept is that the capabilities of the evolving observational program should most directly bear on those tasks identified by the scientific and operational communities that are both essential for meeting societal demands for improved services, as well as capable of being undertaken within the time and resources available. Within this context, three tasks have been given priority by the U.S. Weather Research Program (USWRP) and adopted for the NAOS Program. These are to make improvements in (1) the forecasts of hurricane tracks and intensities, emphasizing landfalling systems, (2) the short- and mid-term quantitative forecasts of precipitation, and (3) the general 1-to-3 day forecasts over the North American continent.

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The second concept is that the observing strategy that would best support such forecast improvements can be organized around recommendations arising from a program of carefully designed scientific, engineering, and operational evaluations of existing and proposed observing systems and data bases. These recommendations must be made in the context of the changing role of government and of restricted budgets.

The NAOS Program encompasses all those activities required to provide management with the recommendations and guidance needed to make decisions on developing that observing strategy. The scope, however, does not include the operational implementation of observing systems.

The NAOS Program activities can be considered as falling into a series of interlocking phases, many of which will be conducted in parallel. The phases are (1) to propose hypotheses on observing system design and parameters to be measured, which will be tested and evaluated systematically during the NAOS Program, (2) to generate the NAOS Program test and evaluation plan that will guide the work, (3) to conduct the scientific and operational tests and evaluations, (4) to provide assessments and conclusions, and (5) to make recommendations to management. Not only will several phases be conducted in parallel, but iterations will be made in the NAOS Program process, where results of one phase may be used to reformulate earlier ones.

The most immediate questions to be addressed by the NAOS Program, however, concern how to make the current upper air observing system more effective and how to make better use of the data that currently are available. Answers to such questions cannot wait for the transition to COS-21 to occur, and must be integrated into the overall strategy as quickly as possible. The initial recommendations emanating from the NAOS Program, then, will be on how to make early changes to the observing program; these will constitute the first steps in building the COS-21.

To be effective, the decision process on how to improve and operate the atmospheric observing system over North America must be coordinated and shared. It is essential, therefore, that the responsible governments, national agencies, and organizations form partnerships to participate

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actively in the NAOS Program. One of these important partnerships is with the USWRP. A vital part of the scientific and technical assessments will be conducted under the USWRP. This program brings together the resources of a wide variety of governmental agencies, research organizations, and universities. Another of the important partnerships is with the international participants whose applicable research results will be factored into the NAOS Program scientific activities. The ability to focus the resources of both the national and international participants on clearly defined objectives is one of the major strengths of the NAOS Program.

The NAOS Program Plan describes how the issues will be defined, how the resources will be identified and coordinated, and outlines the process by which management will be able to make informed decisions on observing system implementation and operation. It includes, in the Appendices, the Terms of Reference for the initial organizations needed to conduct the work of the NAOS Program. The companion NAOS Program Implementation Plan details the milestones and schedule for achieving the objectives.

# **North American Atmospheric Observing System (NAOS)**

## **Program Plan**

### **1. BASIS FOR THE NAOS PROGRAM**

Late 20th century society in North America is complex. That complexity is forecast to increase as technological advances continue to be made in weather-sensitive activities such as commerce, aviation, surface transportation, agriculture, and leisure. These advances have made the well being of the people more, rather than less, dependent on weather information.

Past and present weather-related scenarios indicate the need for improved weather information. The hurricane seasons of the early 1990s caused billions of dollars in damages and diverted additional billions into relief and assistance programs. Economic development along the eastern and southern seaboards will increase over the coming decades, as will the potential for devastating loss due to hurricanes. Major winter storms and super complexes of severe weather can and do shut down cities and even whole sections of the country. Construction of mega-airports and airline hubs will make air transportation even more vulnerable to weather. Industry and consumer outlets, with their concept of "just-in-time" delivery of supplies, have sustained significant losses as a result of the breakdown in transportation during storms. Water management has become critical in large sections of the country due to both intensive agricultural practices and changing patterns of precipitation. The wise use of energy and natural resources, as well as the health of the environment are dependent upon informed decisions, based in large part on weather and climate information.

Not all weather-related impacts can be avoided. Strategies are available to society however, to ameliorate dramatically the impact of weather, given adequate forecasts and climatological information. The U.S. Weather Research Program (USWRP) has examined the possible responses of the scientific and operational meteorological communities in support of societal

## North American Atmospheric Observing System Program Plan

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strategies to cope with weather events. Priority tasks have been identified by the USWRP as being essential to complete if those strategies are to be successful. Three of the high-priority tasks identified by the USWRP, which are within the capabilities of science and technology to address, are

- (1) to improve quantitative precipitation forecasts in the 0-to-6 hour and 6-to-48 hour ranges, especially through better use of observations,
- (2) to investigate appropriate mixes of observations over the eastern Pacific Ocean for improving 2-to-5 day forecasts over the United States, and
- (3) to make better hurricane track and intensity forecasts, with emphasis on landfalling storms.

These tasks, while not new, provide important guidance on where societal needs are the most urgent, and where improvements have the greatest potential benefits.

Each task has been addressed by meteorological organizations, and progress has been made, for example, through the enhanced ability to measure and model the natural environment. Further, the widespread use of computers has enabled the forecasters at field offices to use both existing numerical products and to create a range of new products and services for their customers. In fact, the net result of the modernization of the several national weather services in North America, the advances in numerical modeling, increased field capability, and the successful research efforts has laid the foundation for advancing environmental forecasting into the next century.

The observing program, however, has become one of the most serious obstacles to realizing those possibilities. Advances in the operational observing program have not kept pace with those in numerical weather prediction or the provision of weather services. Both of these latter sets of activities are severely affected by a lack of high quality data that adequately describe weather events on needed time and space scales.

Although significant new capability to observe the atmosphere have been implemented in recent years, gaps remain in certain types of observations, particularly in their temporal and spatial density. At the same time, several different observing systems or techniques are capable of obtaining the same or similar data, while others may no longer be cost-effective to operate. In addition new observational techniques, offering real promise, have not yet been tested systematically, nor have the data they provide been evaluated for operational use. It is clear that technological advances in observing systems have not been supported by a decision process that fosters an integrated approach to the design, implementation, and operation of the observing program over North America.

The observing system problem facing management is twofold. First, a comprehensive set of recommendations does not exist on how to proceed from the present observing system to the future cost-effective composite observing system. Second, an integrated approach is not yet in place to create that future observing system, which includes all of the participants essential to its successful design, implementation, and operation. Forging partnerships amongst these participants is a priority task for management.

Lacking a set of recommendations and an integrated approach, senior management is at a serious disadvantage in making fundamental decisions on how to take advantage of the technological advances to provide the data that will be required over the coming years. Compounding the problem is the fact that the role of government is changing fundamentally at a time when the demand for improved services continues to increase while budgets continue to decrease. The net effect is that management must seek innovative ways (1) to make more effective use of the existing capabilities and data, (2) to take advantage of new technology to create and keep current a more cost-effective observing system with enhanced capabilities, and (3) to improve the governmental decision process on the development of a coherent observing strategy for the 21st Century.

The North American Atmospheric Observing System (NAOS) Program has been created to bring together the scientific, engineering, and management talents needed to accomplish these tasks.

## **2. NAOS PROGRAM GOAL, OBJECTIVES, SCOPE, AND ORGANIZATION**

### **2.1 Goal and Objectives**

The goal of the North American Atmospheric Observing System (NAOS) Program is to provide the scientific, technical and administrative basis for governmental decision processes on how to meet the evolving needs for atmospheric observations over the region of North America and adjacent ocean areas in support of the prediction and assessment of weather and of associated climate services. By providing such a basis, the NAOS Program will serve to reduce the uncertainties and risks in making those decisions, and to improve the decision process itself.

To work toward the goal, three objectives have been identified:

- (1) to assess and make recommendations on the short-term steps that can be taken to improve the utility of the existing observing program, and to reduce costs,
- (2) to define the "best mix" of observing systems, strategies and technologies that meet the requirements in the most cost-effective way for the evolving composite observing system for the 21st century (COS-21), and
- (3) to describe the steps needed to implement and operate COS-21 and to effectively use the resulting data.

The COS-21 design is intended to be the foundation upon which the future observing strategy is built. This design will include a definition of the characteristics of the observations to be obtained and their spatial and temporal distribution, and a description of the operational capabilities needed to obtain them. The design, however, is not a specific configuration fixed at a point in time. Rather, it is composed of a series of time-phased configurations that ensure that COS-21 continues to represent the "best mix" even as the societal needs evolve and observing system capabilities change.

## 2.2 Program Scope

The NAOS Program activities will be concerned with those atmospheric observations needed to support governmental responsibilities for the preparation of

- (1) severe weather watches and warnings,
- (2) short and medium term regionalized forecasts, and
- (3) global 1-to-3 day forecasts as they apply over the North American continent.

Initially, the scope of the NAOS Program will be focused on upper air observations. The activities will then expand to those other observations essential to fulfilling the above three sets of responsibilities. The NAOS Program also will accommodate those climate prediction and assessment activities that rely on these observations.

The scientific scope of the NAOS Program is defined (1) by the three tasks identified by the USWRP (see Section 1), and (2) by the proven set of scientific and operational analysis and evaluation techniques described in Section 3, and illustrated in Figure 1. A major part of the scientific activities will be conducted under the umbrella of the USWRP, and will involve universities, cooperative institutes, and governmental organizations. The methodology for designing and conducting the program of scientific,

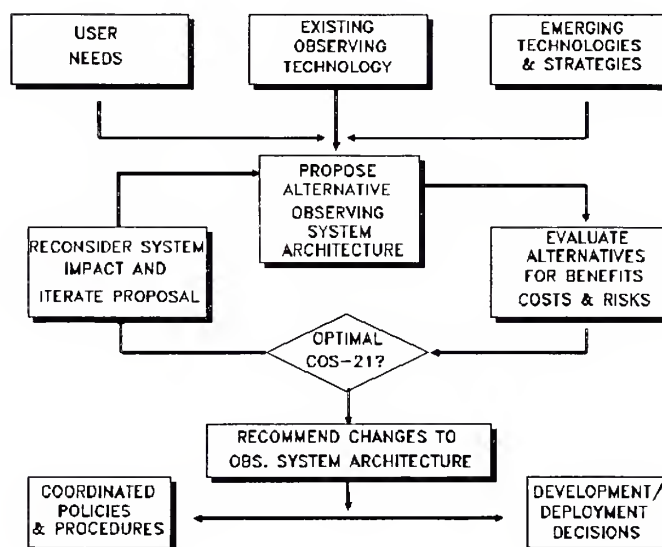


Figure 1: NAOS Decision Process

## North American Atmospheric Observing System Program Plan

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engineering, and operational evaluations of existing and proposed observing systems and data bases is contained in Section 3 and the NAOS Implementation Plan.

Geographically, the NAOS Program will focus its recommendations on the observing system that covers the surface and atmospheric regions within the direct responsibilities of the national participants. In the first instance, this includes the North American continent and adjacent waters. In developing recommendations on the COS-21 design, however, the NAOS Program will consider whatever data over whatever areas and time periods as may be needed to draw scientifically sound conclusions.

The scope of the NAOS Program includes all those activities required to provide management with the recommendations and guidance needed to make decisions on developing an observing strategy for the 21st century. The scope, however, does not include the operational implementation of observing systems.

### 2.3 Program Organization and Management

NAOS activities are supported by the National Oceanic and Atmospheric Administration (NOAA) management structure shown in Figure 2. A NAOS Program Council has been established to provide leadership and guidance on the conduct of the NAOS Program activities. Through internal coordination amongst governmental agencies, the NAOS Program will bring together a significant scientific

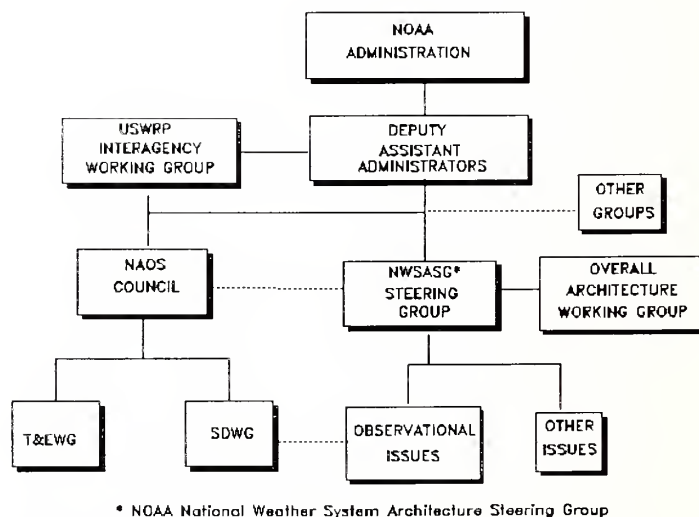


Figure 2: Management Structure Supporting NAOS Activities

and operational capability to participate in the work of the NAOS Program Council. In creating the Council, consideration was given to the fact that an important amount of the atmospheric observations of concern to the NAOS Program comes about through multilateral international cooperation and bilateral agreements with Canada, Mexico, and Caribbean countries. In turn, any improvements in the composite observing program will be of direct benefit to neighboring countries. An objective in forming the Council, therefore, was to obtain appropriate international participation. (The Terms of Reference for the Council and membership are shown in Appendix A.)

The initial NAOS Council is composed of Regular Members who will represent the NOAA Line Organizations, NOAA Office of Global Programs, USWRP, National Aeronautics and Space Administration (NASA), Department of Defense (DoD), Federal Aviation Administration (FAA), National Science Foundation (NSF), and other U.S. Federal agencies with closely related missions. In addition, Technical Experts and Advisors will be designated to provide the NAOS Council with a range of scientific and technical expertise. The chairs of the Work Groups established by the Council will participate in the work of the Council. Representatives from the national meteorological services of the international participants, initially Canada and Mexico, will be invited to participate. Occasionally, individuals from a broad group of organizations with special involvement in specific issues will be invited to participate directly in the work of the Council.

The Council initially has established the Test and Evaluation Work Group (T&EWG) and the System Design Work Group (SDWG) to conduct studies and analyses and to provide the Council with results relating to the design of the COS-21. (See Section 3.1 and Appendix B for the Terms of Reference and membership for these two groups.) The T&EWG will be responsible for conducting studies and analyses to evaluate the ability of the various configurations of observing systems proposed to satisfy the requirements for data, and will identify the expected benefits to be obtained. The SDWG will be concerned with the operational costs, benefits, and risks of the configurations proposed and evaluated by the T&EWG.

The NAOS Program cannot evolve in isolation. Nor can the decisions on development or deployment be reached without careful coordination with existing policies. The guidelines of the strategic operational plans of the participants, for example, have to be given serious consideration in how the NAOS Program is conducted. Therefore, an iterative interaction with long-term planning activities is an integral part of the NAOS Program process.

Within NOAA, the NOAA National Weather System Architecture Steering Group (NWSASG) works with the NAOS Council (Figure 2) to ensure that the strategic implications of any changes to the observing program are fully integrated into the recommendations made to the NOAA Deputy Assistant Administrators (DAAs). Organizations other than NOAA will have their own mechanisms for incorporating the results of the NAOS Program into their strategic planning.

### **2.4 Program and Global Observing Strategies**

Scientists from many countries have been working together for decades to define and plan new networks of observing systems that will provide both insitu and remote sensing of the Earth's atmosphere, oceans and land areas. A recent example is the Global Climate Observing System (GCOS), which is intended to acquire systematic long-term observations as required to monitor and characterize all aspects of climate. Another example is the Global Ocean Observing System (GOOS). This program is intended to acquire oceanic observations to monitor (1) living marine resources, (2) the coastal zone environment, and (3) the health of the ocean, as well as to continue to provide marine meteorological and operational ocean observations. Together, these and other global observing programs can be considered as being part of the group of global climate, ocean, and terrestrial observing systems.

The scope of the NAOS Program includes those climate activities that rely on observations from an observing system whose primary function is to meet the needs of weather forecasting and assessment out to three days over the North American region. In this regard, the results of the NAOS Program will complement the activities of those seeking to devise strategies for an integrated global observing system that would most efficiently serve the needs of the global community. Of special importance to international planning activities would be to consider how

the NAOS Program results can be used to develop strategies that would minimize duplication and would encourage complementarity between the several components of the global observing program.

The recommendations stemming from the NAOS Program, while directed primarily toward the areas and activities under the responsibilities of the participants, will very likely have application elsewhere. Also, some recommendations to be most effective may require coordinated action by a wide variety of national and international activities not directly a part of the NAOS Program. To the extent possible, the NAOS Council will assist in efforts to have such recommendations considered by appropriate national and international organizations.

### **3. SCIENTIFIC AND TECHNICAL ACTIVITIES**

#### **3.1 Organization of the Scientific and Technical Program**

The scientific/technical activities for NAOS are organized around the three Program objectives. This organization is carried through to the NAOS Implementation Plan. Restated, the objectives are to provide recommendations (1) on the short-term steps that can be taken to improve the existing observing system and reduce costs, and (2) on the design of the COS-21. The third objective is to define the steps needed to implement the recommendations. The recommendations will be based on the results of a comprehensive program of scientific and technical assessments involving the capabilities of a variety of U.S. governmental organizations, as well as those of other countries and organizations with a direct interest in the NAOS Program.

The two NAOS Work Groups (and others as may be formed later) are responsible for organizing and managing the work program, and for coordinating the activities of the work group participants. Members of both the T&EWG and the SDWG will represent (1) individual groups conducting scientific and technical activities under NAOS, including those groups receiving significant grants to conduct NAOS work, (2) larger organizations making a variety of contributions to NAOS activities, such as the NSF, (3) scientific/technical disciplines important to the success of NAOS, and (4) international participants and relevant organizations.

As a practical matter of size, not all those contributing to the Work Groups can be members. It is desirable, however, that some or all of the members on the Work Groups be directly engaged in the NAOS work program.

Many of the fundamental research activities supporting the NAOS program fit under the broad umbrella of the USWRP. NOAA and the NSF have agreed that the first major joint research effort carried out under the USWRP would be a significant component of the NAOS Program research activities. To make maximum use of the capabilities of the USWRP, emphasis will be placed on obtaining participation of the general research and scientific communities. Testing and evaluation, and the examination of system support needs will be carried out jointly by groups in NOAA; NCAR; Canada, Mexico, other international participants; universities; cooperative institutes; and related organizations within the scope outlined by the NAOS Council.

### 3.2 Methodology

The scientific and technical activities can be considered as being organized into a series of interlocking steps, several of which will be conducted in parallel. These steps are as follows:

- propose hypotheses on observing system design and parameters to be measured, which will be tested and evaluated systematically during the NAOS Program.
- generate the NAOS Program test and evaluation plan, which will guide the work.
- conduct the scientific and operational tests and evaluations.
- provide assessments and conclusions.
- make recommendations to management.

Not only will several steps be conducted in parallel, but there will also be iterations in the NAOS Program process where the results of one step will be used to reformulate others.

### **3.2.1 Scientific test and evaluation activities**

The scientific test and evaluation activities will be concerned with identifying the expected improvements to forecasts arising from changes to the observing program. These activities will emphasize primarily the use of numerical techniques. For these techniques to be effective, there is a particular need for the reliable transmission of observations, for appropriate formatting and quality control of the incoming data, and for an objective analysis package that can provide reliable and consistent input to the evaluation techniques.

Numerical evaluation techniques require significant computational resources. These resources are comparable to those required for operational numerical weather prediction. Only a limited number of centers are capable of conducting the evaluations, and these either run or are capable of running the operational models. At operational centers, only limited amounts of time are available for non-operational work. At other centers, research and development activities severely tax the computer resources, and often are in direct support of improvements to the operational models. To use the limited resources effectively and to obtain scientifically valid results, carefully framed questions must be posed before the experiments are designed and conducted.

Although the primary emphasis will be on numerical techniques, theoretical simulations and laboratory evaluations will have important roles in the scientific program. Some of the major techniques to be used are discussed briefly below:

#### **Data sensitivity tests**

Data sensitivity tests use actual observations. The most straightforward experiments may be characterized as data-denial or data-inclusion experiments. An assimilation-prediction system is run with a control data set, and then with one or more data types withheld, or reduced in quantity. Analyses or forecasts are verified against observations. Comparison of the two runs shows the effect of data denial, or, equivalently, the value of the observing system when

included. Data sensitivity tests are valuable, for example, in examining the impact of making temporal or spatial changes in the network configuration, or of adding or deleting existing observing systems, without actually making the changes.

### **Observing system simulation experiments (OSSEs)**

OSSEs deal with hypothetical or simulated data sets, as opposed to data sensitivity tests, which deal with actual observations. OSSEs are useful for estimating how an entirely new observing system might affect forecast accuracy. A historical forecast is usually designated as the control run; it describes the "true" atmosphere. Hypothetical observations with plausible error characteristics are then manufactured from the control run at designated locations and times. The observational data set to be examined is then assimilated by a prediction model, and a new forecast is generated in parallel with the control forecast. The impact of the simulated observing system is approximated by the difference between the two forecasts. OSSEs, despite their limitation to hypothetical observations, are an important part of assessing the potential utility of data from a system before it is actually implemented.

### **Theoretical studies and simulations**

Theoretical studies and simulations of expected data utility from potential future sensor systems are a further abstraction from reality, but can be important in planning changes to the existing observing system. For example, substantial theoretical studies and simulations were conducted prior to the launch of the first GOES I-M series of satellites to predict the performance of the sensors. The results of this work provided an important part of the basis for designing the ground data processing system, as well as many other aspects of the support facilities required. As systems become more and more complex and costly, the need for well-planned theoretical studies and simulations will increase. They are a vital way to reduce the risk of making decisions to develop and implement systems still in the conceptual or research stage.

## **Laboratory evaluations**

Some evaluations, particularly of data processing and display techniques, are best and/or more economically conducted in a controlled laboratory environment. The facilities of the NOAA Environmental Research Laboratories, (ERL), NCAR and University Corporation for Atmospheric Research (UCAR), for example, have extensive capability to develop and evaluate a wide range of new techniques for data processing and display. The results from their work have been instrumental in designing both individual sensor suites and networks. Similarly, universities, cooperative institutes, and laboratories at NASA and DoD facilities have made major contributions to sensor development and concepts of how to configure networks to meet specified requirements.

### **3.2.2 System design and analysis activities**

The system design and analysis activities are concerned primarily with identifying the cost and operational impact of recommended changes stemming from the scientific studies. These activities also include the design and coordination of any field and/or pilot projects that may be needed. Several of the types of system design and analysis activities are described below:

#### **Baseline inventory and technology assessment**

The purpose of the baseline inventory is to obtain a "profile" of the existing upper air observing system. The inventory will define (1) the parameters measured and their implicit relationships (such as between radiance and thickness), (2) its operational and engineering performance, (3) its life-cycle costs, and (4) the system-wide impact of making changes.

The technology assessment will include existing observing systems, those in the process of being implemented, and those proposed which have a high potential. For the new and proposed systems, the technology assessment will include a description of the expected performance, cost, and operational impact. Estimates will be made of the time and cost of demonstrating operational feasibility.

## **North American Atmospheric Observing System Program Plan**

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### **Scenario and "best mix" evaluations**

Based on the recommendations of the T&EWG, scenarios will be formulated that emulate operational network configurations. Trade-off analyses will be made to test the recommended configurations for cost, operational viability, and practicality of being implemented.

Life-cycle cost will be estimated for development, operation, maintenance, support, and disposal over the anticipated service life of the systems included in the different COS-21 configurations. The initial set of cost estimates will be updated routinely. Candidate configurations may be added or dropped during the update process as new sensors and data processors emerge.

### **Architecture and transition planning**

Once the analyses of cost and operational impact and viability have been conducted, issues still will remain on how best to evolve from the current system to the COS-21 in view of the strategic plans of the participants. As part of the observational activities of the appropriate working groups, recommendations on proposed changes to the operational observing system will be reviewed to determine the impact on the overall architectural designs of the national weather services. Questions will be addressed, such as, do the proposed changes and the proposed architecture for the COS-21 make sense with respect to an evolutionary change from the current system? Do the proposed changes serve to advance the overall effectiveness of the observing system over North America? Iterations amongst the T&EWG, the SDWG, and the NOAA National Weather System Architecture Steering Group (NWSASG) will be essential to converge on any of the NAOS recommendations.

### **Development and demonstration**

Pilot/demonstration projects. Pilot/demonstration projects have been used extensively for a long period to examine the operational issues of deploying a network of new sensor systems as well as to prove a concept by obtaining a reliable data base under operational conditions. A demonstration project, for example, has been conducted for some years in Colorado to examine

the utility for mesoscale and microscale forecasting of data from a dense surface observing network in combination with other data. One of the more recent and successful examples is the NOAA Wind Profiler Demonstration Network, now termed the NOAA Profiler Network.

The entire atmospheric observing system is a highly complex ensemble of sensors, sensor systems, and data processing capabilities. These provide data sets with very different temporal and spatial coverages and data accuracies. The introduction of new systems into this ensemble will engender issues difficult or impossible to foresee in the abstract. Pilot/demonstration projects have become a cost-effective mechanism to document the operational characteristics and support requirements of both the new systems and the new configuration before large-scale deployment is made. Again, the information obtained from pilot/demonstrations will reduce significantly the risk of making decisions on the implementation of the COS-21.

Field site evaluations. Existing field sites offer a unique opportunity to examine the impact new data sets could have on forecasting and on the generation of products. Some of the demonstration results mentioned above for the Colorado surface observing network and the wind profiler came directly from evaluations conducted at operational field sites. Both ERL and NCAR have been particularly active in using field sites to obtain critical information on the value of new data processing and display techniques, and mesoscale modeling in operational situations. Field site evaluations become especially important in both the early and late stages of development/deployment to ensure that operational support is defined properly, is in place when needed, and that the field personnel are trained to obtain the best results from the new systems.

Visualization concepts. As the complexity of systems and their interactions in composite networks increase, so will the need increase to develop creative ways to examine concepts. One way, for example, is to create a "virtual" observing system in the laboratory on computers so that changes could be visualized in four dimensions. The virtual system would be a model accommodating the existing, proposed, and planned networks. The model could be manipulated to examine "what if" questions about network design and operation. The virtual system also could be used to narrow the possible configurations to a few most likely that then could be

evaluated scientifically. This would focus the scientific activities and help to conserve expensive and limited computing resources. The NAOS Program will rely increasingly on such innovative ways to provide information on sensor and network capabilities long before they could become operational.

#### **4. PROGRAM IMPLEMENTATION ACTIONS AND SCHEDULE**

The NAOS Implementation Plan will set down the work required to realize the goals established in the NAOS Program Plan. Specifically, the Implementation Plan will stress three main areas: (1) organization and management, (2) conduct of the scientific and technical activities, and (3) the preparation of recommendations and reports. This section of the Program Plan includes basics on these three areas. The details will be contained in the separate NAOS Implementation Plan.

##### **4.1 Organization and Management Functions**

The following actions were identified as the initial set of actions required to implement the organizational and management functions:

- Establish the NAOS Council and the T&EWG and SDWG; appoint the Executive Secretary and establish the Secretariat.
- Agree on the work programs for the T&EWG and the SDWG and establish work priorities; this includes reaching agreement on the hypotheses to be tested and the overall testing strategy.
- Define the initial resource requirements.
- Prepare the Implementation Plan.

- Establish the procedures for working with the USWRP Interagency Working Group.
- Develop working arrangements with participating organizations, such as other U.S. Federal agencies, international participants, universities, and cooperative institutes.

#### **4.2 Scientific and Technical Work Program**

The scientific and technical work program is organized according to the three NAOS Program objectives (Section 2.1). The first two, recommendations on the existing system and the design of the COS-21, form the framework for the work program. The third objective, the actions needed to implement the recommendations, supports the first two and ties the work program directly to the decisions management needs to make.

Specific actions are the following:

- Identify the scientific, technical, and operational issues to be addressed and formulate questions to be answered by the NAOS Program groups.
- Establish the methodology for conducting the evaluations. This step includes agreeing on the types of evaluations to be conducted (such as OSSEs, data sensitivity tests, and field demonstrations), as well as the techniques to be used (such as the models, the acceptable level of statistical reliability, and data assimilation strategies).
- Identify the existing research activities that can be oriented toward the NAOS Program work program; make specific proposals to organizations for support.
- Coordinate existing research and development efforts so that the most urgent issues identified by the NAOS Program Council can be addressed; special

attention should be given to those efforts dealing with upper air data sets, such as improved satellite observations, Global Positioning System (GPS) water vapor studies, efforts to establish links to new Aircraft Communications and Reporting System (ACARS) data sets, and OSSEs involving the profiler network.

- Organize and conduct data sensitivity studies, OSSEs, and field evaluations to validate requirements from a composite observing network for use in numerical weather prediction (NWP) models, and in support of field forecasting.
- Organize evaluations aimed at determining the operational support required of proposed new observing systems; these might include pilot projects and/or field site evaluations.
- Explore the possibilities for using advanced concepts in data base management and simulations to examine proposed network configurations; these might include, for example, the establishment of an adapted version of a Geographic Information System, and/or a computer-based "virtual" observing system network for use in describing and assessing the possibilities for a COS-21.

### **4.3 Preparation of Recommendations and Reports**

As part of the observational activities of the appropriate work groups, recommendations on proposed changes to the operational observing system will be reviewed to determine the impact on the overall architectural designs of the various national weather services. Iterations amongst the T&EWG, the SDWG, and the NOAA National Weather System Architecture Work Group will be essential to fulfill on any of the NAOS recommendations.

The results of analyses of the NAOS work groups will be presented in the form of (1) a series of recommendations on improvements to the existing observing program, and (2) a recommended configuration for the COS-21, and possible alternatives, together with information supporting

the expected operational and managerial decisions concerning its implementation. The actions needed to implement the techniques for analyzing the recommendations have been identified in the preceding two sections.

An important part of the NAOS Program activities is to make the scientific community aware of the work in progress and to share the scientific results. An effort will be made through the Council to ensure that appropriate papers and presentations are prepared for scientific journals and meetings.

#### **4.4 Modernization of the Program for Obtaining Upper Air Measurements**

In developing assessments of the resources required, it was recognized that funds from all sources would be limited. Many more questions could be posed than could be answered by using the resources likely to be made available. Priorities, therefore, were established to emphasize the most pressing issues. For this reason, the issue concerning the modernization of the program to obtain upper air measurements was given high priority for the early period of NAOS activities.

Of special importance during this early period is to determine the most effective use of (1) new GOES capabilities, (2) wind and temperature profilers, (3) commercial aircraft to obtain automatically in-flight and sounding data, and especially the possibility of obtaining humidity profiles, and (4) Doppler radars.

In particular, the following activities have been identified:

- Organize and conduct data sensitivity studies and OSSEs to examine the requirements for upper air data in the context of the current and anticipated models. These studies likely will be subsets of work done to generally substantiate requirements for observational data. Basic questions are to be addressed on the parameters to be measured, the sampling frequency and spatial resolution required, the impact of the data from current observing systems on

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NWP models, and the best probable mix of systems, those either operational at present or feasible to deploy.

- Give special attention to the individual and combined roles of profilers, satellites, and aircraft in the modernization of the program to obtain upper air measurements.
- Organize theoretical studies and simulations to examine the potential for obtaining data from new or proposed observational concepts, such as using satellite-based occultation measurements.
- Examine the need for, and organize as agreed, pilot and/or demonstration projects to prove the feasibility of new upper air measuring techniques.

### 4.5 Schedule

The NAOS Program has been established and an initial set of activities have been identified through FY 1999. During this period the scientific and technical activities will be initiated and the first results on the design for the future upper air observing system will be provided to management. The schedule for the years after FY 1999 will depend upon the progress made, the acceptance of the recommendations, the results of research and development programs into new observing techniques, the nature of the future questions needing answers, and available resources.

The broad outline of the schedule through FY 1999 is outlined below:

|               |                                                                                                                         |
|---------------|-------------------------------------------------------------------------------------------------------------------------|
| Early FY 1997 | Formulate hypotheses, assemble the resources needed to test them and begin the testing activities.                      |
| Early FY 1998 | Complete the initial hypotheses testing, complete the design of the operational scenarios for evaluation, and establish |

any needed field demonstration projects.

Late FY 1998

Complete any field demonstrations, scenario analyses, and recommendations on transitional planning.

Early FY 1999

NAOS Council makes initial recommendations to management on changes to the upper air observing program.

## **APPENDIX A: NAOS ORGANIZATIONAL CHARTER**

The NAOS Program has established a Council to provide leadership and guidance in conducting its activities. The Council's responsibilities, participants, chair, support, and procedures are set forth in this charter. This charter shall be reviewed by the Council with DAA concurrence, and shall remain in effect until superseded by a revised charter that has been approved by a majority of the members.

### **COUNCIL RESPONSIBILITIES**

- Establish policy with respect to planning and implementation of the NAOS Program.
- Define the schedule and the resources needed to organize and conduct the NAOS Program.
- Seek and/or contribute existing resources, as available, to support NAOS Council and Work Group activities.
- Provide guidance to the executives of the participating organizations on the most effective and efficient operation of current and future observing systems to meet the evolving governmental requirements for atmospheric observations over North America and the adjacent oceans.
- Cooperate with the participating agencies and international participants to meet NAOS Program objectives.
- Have the special responsibility (1) to coordinate with the NOAA National Weather System Architecture Steering Group to ensure that the strategic implications of

any changes to the observing program are fully integrated into the recommendations made to the Deputy Assistant Administrators (DAAs) and other U.S. program participants, and (2) at the request of NOAA Line Offices (LOs) or appropriate program office, to review recommendations for modification to NOAA's observing system.

- Assist, as appropriate, International Participants in formulating recommendations for their governments on the observing program that would be compatible with both the evolving composite observing system over North America and their national strategies.
- Provide the primary point-of-contact for working with organizations outside of the NAOS structure.
- Establish and manage NAOS Work Groups, initially forming two and appointing their members. The two Work Groups are the Test and Evaluation Work Group (T&EWG) and the System Design Work Group (SDWG). The chairs of the Work Groups will sit as advisors on the NAOS Council.
- Provide guidelines on major issues to be examined by the T&EWG and the SDWG, and agree on the major elements of their respective work programs.

## **COUNCIL PARTICIPANTS**

Participation in Council activities will include Regular Members, International Participants, Associates, and Technical Experts and Advisors. The NAOS Council will decide on what changes in membership may be required to fulfill its responsibilities.

### Regular Members

Regular members of the NAOS Council are:

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- One individual from each NOAA LO, one from the Office of Global Programs, and one from the USWRP.
- one individual each from other U.S. Federal agencies such as NASA, DoD, FAA, and NSF, as well as other U.S. Federal agencies with closely related missions,

### International Participants

One individual each from the international participants, initially the Atmospheric Environment Service (Canada) and the Servicio Meteorológico Nacional (Mexico), will be designated as Associates who will participate regularly in the NAOS Program activities, including those of the Council.

### Associates

Associates will be invited to participate in NAOS Program activities as needed from the following:

- Appropriate universities, meteorological centers, and/or organizations.
- Individuals with special involvement in specific issues.

### Technical Experts and Advisors

The chairs of the Work Groups, the T&EWG and the SDWG will regularly participate in NAOS Council activities as Technical Experts and Advisors.

In addition, Technical Experts and Advisors will be appointed as needed:

- Those who can provide a range of scientific and technical expertise on subjects of concern to the work of the NAOS Council,

- from the International Participants to assist in the overall work of the NAOS Program and to provide special expertise on multinational issues.

## **COUNCIL CHAIR**

The Chairman of the NAOS Council is appointed by the NOAA Deputy AAs. Since the recommendations of the NAOS Council could affect major aspects of NOAA policy, the Chair of the NAOS Council will be selected from NOAA.

The Chair has the following responsibilities:

- Represent NAOS as a whole, not individual organizational interests.
- Develop an integrated program implementation plan; the plan will be reviewed and updated periodically.
- Develop overall NAOS budget strategy and coordinate annual budgets for specific activities.
- Lead the NAOS Council meetings.
- Represent NAOS at meetings, workshops, and other official functions.
- Represent NAOS with other U.S. Federal agencies, other countries, and intergovernmental organizations.
- Present briefings on Council and Work Group activities to the DAAs, executives of other participating agencies and international participants, the NOAA National Weather System Architecture Steering Group, the USWRP Interagency Working Group, and others as appropriate.

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- Assign a NAOS representative to the NOAA National Weather System Architecture Steering Group.

### **COUNCIL SUPPORT**

A Secretariat function will be established. It will be led by an Executive Secretary who will be responsible for providing the administrative and programmatic support for Council and Chair activities. The Executive Secretary has the following responsibilities:

- Prepare agendas and organize the meetings.
- Prepare minutes of meetings, distribute action items, document decisions made, and ensure progress is made toward their closure.
- Coordinate the development of reports and other documents required by the NAOS Council.
- Represent NAOS at meetings and other official functions when the Chairman is unable to do so.
- Work with the Chairman to develop the Implementation Plan, and annually update budgets.
- Prepare NAOS Program status reports as needed and provide continuity for NAOS Council and work group activities.
- Coordinate the work of the T&EWG, the SDWG, and other appropriate groups, in accordance with the direction of the NAOS Council.
- Maintain technical expertise on material relevant to NAOS activities.

## **COUNCIL PROCEDURES**

The procedures of the Council are as follows:

- Member may designate an alternate to represent them at meetings during their absence.
- The Council will meet at the call of the Chair and is to meet no less than twice a year. Participation will be limited to regular Members, Associates, Technical Experts and Advisors, and additional participants approved by the Chair.
- The Council Chair will represent the views of the members in making recommendations to the responsible management officials such as the DAAs in NOAA.
- Agendas, minutes, and records of actions shall be prepared and disseminated in a timely manner by the Executive Secretariat.
- Actions, reports and recommendations of the Council will be by consensus rather than by voting. Minority opinions and reports will be encouraged as necessary to fully reflect the views of the Council. As necessary, the Chair will be responsible for seeking resolution of issues through the executives of the participating agencies and International Participants.
- The NAOS Council will work within the resources available from the participants. Initially, existing resources will be the prime source of support.

## **APPENDIX B: CHARTER FOR NAOS WORK GROUPS**

The NAOS Council will establish Work Groups (WG) to carry out activities to accomplish the goals of the Program. Initially the Council will form a Test and Evaluation WG (T&EWG) and a System Design WG (SDWG). The main functions of the Work Groups are to guide and coordinate efforts, interpret results, and draw conclusions rather than to manage the NAOS evaluation and design efforts.

### **WORK GROUP RESPONSIBILITIES**

The following are the responsibilities of the initial two work groups.

#### **T&EWG**

- Develop a work program based on the guidance provided by the NAOS Council. This work program will be fully integrated with that of the SDWG and other WGs, and will emphasize the creation of the scientific/technical basis for recommendations on improvements to the existing system and on the design of the COS-21, its implementation and support.
- Work directly with appropriate organizations participating in the NAOS activities to implement the agreed work program, including assisting these organizations to plan and initiate studies, evaluations, and pilot/demonstration projects.
- Organize and coordinate special studies and data assimilation experiments, field evaluations, and pilot/demonstration projects based on plans approved by the Council.
- Receive reports, studies, and analyses of the relevant NAOS activities; prepare

assessments of this material; and prepare recommendations both to the organizations conducting the activities and the NAOS Council. These recommendations could include, for example, proposals for additional efforts and/or funding required, or changes in the direction of the activities.

- On the basis of information available to it, (1) propose changes to the existing observing network that would make it more efficient, less costly, and better able to meet the requirements for data, (2) propose candidate observing systems and techniques to be integrated into the COS-21, and (3) propose the optimal configuration for the COS-21.
- Work with the SDWG and other WGs to determine the potential benefits and risks involved with the implementation of any of the observing system proposals.
- Provide to the NAOS Council scientific/technical assessments concerning the potential impact of proposed observing systems and configurations for the COS-21 on the overall capability of governmental agencies to fulfill their missions.

## **SDWG**

- Develop and implement systems and engineering oriented activities in response to guidance from the Council, fully integrated with the efforts of the T&EWG and other supporting WGs, to achieve NAOS goals.
- Work with the T&EWG and other WGs to identify and deliver candidate observing system data needed for the scientific determination of the utility of proposed composite system configurations.
- Plan and coordinate the development and demonstration of emerging observing technologies to provide meteorological data for scientific studies and engineering

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assessment information including cost, performance, and operational maintenance for composite system cost-effectiveness analyses.

- Coordinate with the NOAA National Weather System Architecture Working Group to assess potential impacts on operations and system architecture, and to ensure consistency with the strategic planning of the NOAA National Weather Service.
- As agreed by the Council, coordinate with the appropriate groups of the weather services of the International Participants to assist them in assessing the potential impacts of NAOS recommendations on their operations and system architecture.
- Derive, in cooperation with the T&EWG using results of analyses of meteorological utility, system assessment, and architecture impacts, a family of recommendations for composite observing system cost-effective best-mix configurations coupled with inherent trade-offs for consideration by the Council,
- Coordinate, develop, and draft preliminary plans, studies, and other documents needed to transition to the recommended realization of the operational composite system to achieve NAOS objectives.

### **WORK GROUP MEMBERSHIP**

The membership of the NAOS WGs will be guided and approved by the Council. As a practical matter of size, not all those contributing to the Work Groups can be members. It is desirable, however, that some or all of the members on the Work Groups be directly engaged in the NAOS work program.

Work Group members may represent (1) individual groups conducting scientific and technical activities under NAOS, especially of those groups receiving grants to conduct NAOS work, (2) larger organizations making a variety of contributions to NAOS activities, such as the NSF, (3) International Participants, and (4) scientific/technical disciplines important to the success of

NAOS. The WGs may "co-opt" individuals to participate actively in the accomplishment of their activities including being invited to attend WG meetings as appropriate.

Consideration will be given to inviting the participation on the Work Groups of organizations not otherwise involved with NAOS, but that have special capabilities that could advance the work of NAOS. Special capabilities, for example, could include data assimilation, numerical weather prediction, or test and evaluation of observing systems.

#### **WORK GROUP CHAIRS**

The Work Group Chairs shall be appointed by the Council Chair with approval of the Council.

## APPENDIX C : ACRONYMS

|        |                                                     |
|--------|-----------------------------------------------------|
| AA     | Assistant Administrator                             |
| ACARS  | Aircraft Communications and Reporting System        |
| COS-21 | Composite Observing System for the 21st Century     |
| DoD    | Department of Defense                               |
| DAA    | Deputy Assistant Administrator                      |
| ERL    | Environmental Research Laboratories                 |
| FAA    | Federal Aviation Administration                     |
| GCOS   | Global Climate Observing System                     |
| GOOS   | Global Ocean Observing System                       |
| GPS    | Global Positioning System                           |
| LO     | Line Organization                                   |
| NASA   | National Aeronautics and Space Administration       |
| NCAR   | National Center for Atmospheric Research            |
| NSF    | National Science Foundation                         |
| NWSASG | National Weather System Architecture Steering Group |
| OSSE   | Observing System Simulation Experiment              |
| SDWG   | System Design Work Group                            |
| T&EWG  | Test and Evaluation Work Group                      |
| UCAR   | University Corporation for Atmospheric Research     |
| USWRP  | U.S. Weather Research Program                       |









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